

**FINAL REPORT—BERKELEY PIT INNOVATIVE  
TECHNOLOGIES PROJECTS: H.P.T. RESEARCH,  
INC., DEMONSTRATION**

**MINE WASTE TECHNOLOGY PROGRAM  
ACTIVITY IV, PROJECT 7**

**Prepared by**

Montana Tech of The University of Montana  
1300 W. Park Street  
Butte, Montana 59701  
Report # MWTP-MT-07-05A

**Prepared for**

MSE Technology Applications, Inc.  
P.O. Box 4078  
200 Technology Way  
Butte, Montana 59702

**Prepared for**

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National Risk Management Research Laboratory  
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**REVIEWS AND APPROVALS:**

Prepared by: \_\_\_\_\_  
Project Engineer

Reviewed by: \_\_\_\_\_  
Project Manager

Approved by: \_\_\_\_\_



May 1997

# **Final Report—Berkeley Pit Innovative Technologies Projects: H.P.T. Research, Inc., Demonstration**

## **Demonstration Performed by**

H.P.T. Research, Inc.  
13010 Loma Rica Drive  
Grass Valley, California 95945  
Ph: 916-274-7631  
Fax: 916-274-2750

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## Foreword

Today industries are developing and modifying technologies to more efficiently produce their products. The waste generated by these industries, if improperly dealt with, can threaten public health and degrade the environment. The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the EPA strives to formulate and implement actions leading to a balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define, measure the impacts, and search for solutions to environmental problems.

The National Risk Management Research Laboratory (NRMRL) of EPA is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis. This supports the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. The Federal Energy Technology Center (FETC) of the U.S. Department of Energy (DOE) has responsibilities similar to the NRMRL in that FETC is one of several DOE centers responsible for planning, implementing, and managing research and development programs. In June 1991, an Interagency Agreement (IAG) was signed between EPA and DOE that made funds available to support the Western Environmental Technology Office's operating contractor, MSE Technology Applications, Inc., and Montana Tech of The University of Montana for the development of the Mine Waste Technology Program (MWTP). This publication is one of the products of the research conducted by the MWTP through these two Federal organizations and provides a vital communication link between the researcher and the user community.

The objective of this demonstration was to remove metals, ions, and dissolved solids from the input Berkeley Pit water and to produce water that is fully compliant with Federal, State, and local water standards.

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## **Executive Summary**

Under contract to the Mine Waste Technology Program (MWTP) of Montana Tech of The University of Montana (Montana Tech) in Butte, Montana, H.P.T Research, Inc. (HPT) conducted a bench-scale demonstration of an advanced process for producing statutorily compliant water from Berkeley Pit water.

The innovative remediation technologies conducted during this demonstration have shown the following:

- the ability of the HPT Acid Mine Drainage (AMD) processes to remove metal ions from the Berkeley Pit waters to near or below equipment detection levels; and
- the ability of the HPT AMD processes to remediate the Berkeley Pit AMD with environmentally safe chemical reagents.

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## CONTENTS

	Page
Foreword . . . . .	ii
Executive Summary . . . . .	iii
Tables . . . . .	v
1. INTRODUCTION . . . . .	1
1.1 Contract . . . . .	1
1.2 Statement of Project Objectives . . . . .	1
1.3 Quality Assurance Project Plan . . . . .	1
1.4 Demonstration Evaluation Standards . . . . .	1
2. HPT TECHNOLOGIES PROCESS DESCRIPTION . . . . .	3
2.1 Bench-Scale Process . . . . .	3
2.2 Conclusion . . . . .	3
3. BENCH-SCALE DEMONSTRATION . . . . .	4
3.1 Data Results . . . . .	4
3.2 Data Locations . . . . .	5
4. CONCLUSIONS . . . . .	6
4.1 General . . . . .	6
4.2 Dissolved and Suspended Metals and Sulfates . . . . .	6
4.3 pH . . . . .	6
4.4 SO <sub>4</sub> . . . . .	6
4.5 Consideration of Alternative Approach . . . . .	6
4.6 New Diagram of Proposed Changes in HPT AMD Process . . . . .	6
Appendix A: Actual Test Data on Berkeley Pit AMD Used for This Test and Final Data Sheets on HPT 7-1 Through 8-1 From ACZ . . . . .	8
Appendix B: Third-Party Test Data from ACZ Where The Calcium Was Not Interfering With ICP Metals . . . . .	35
Appendix C: Third-Party Test Data Done With an Optima ICP Run by Dr. W.H. Chatham At Montana Tech Analytical Lab . . . . .	45
Appendix D: First Lawrence Livermore National Laboratory Non-Custody Samples of Berkeley Pit AMD, Butte, MT, and Iron Mt. Mine, Redding, CA. . . . .	47
Appendix E: Second Lawrence Livermore National Laboratory Tests Custody Samples . . . . .	65
Appendix F: Cover Letter and Report on Third-Party Testing of AMD from Iron Mt. Mine Performed by California State University Fresno Engineering Research Institute, Dr. Barry H. Gump, Principal Investigator . . . . .	75



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## Tables

Page

1-1. Data quality objectives of accuracy, precision, method detection limit, and completeness . . . . .	2
3-1. Demonstration results . . . . .	5

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## **1. Introduction**

### **1.1 Contract**

Under a contract to a portion of the Mine Waste Technology Program (MWTP) being conducted at Montana Tech of The University of Montana (Montana Tech) at Butte, Montana, H.P.T. Research, Inc. (HPT), conducted a bench-scale demonstration of an innovative process for removing metals from acid mine drainage (AMD) from the Berkeley Pit. HPT provided personnel, materials, and technologies required for performance of the demonstration.

Demonstration activities took place in accordance with quality assurance project plan (QAPP) number NRML Ci ID#Z-11076-B, which was jointly prepared and agreed to by HPT and Montana Tech. HPT did not deviate from the QAPP, except on samples 7-4 and 8-1. Part 4 (neutralization) was not performed to simplify ACZ testing.

The final demonstration took place at Montana Tech from October 14 through October 25, 1996.

### **1.2 Statement of Project Objectives**

The objective of this project was to test the ability of the HPT process to remove selected dissolved metals in water taken from the surface and the 200-foot level of the Berkeley Pit. The success of the process was evaluated by measuring the concentrations of aluminum (Al), arsenic (As), cadmium (Cd), copper (Cu), lead (Pb), nickel (Ni), zinc (Zn), and sulfate ( $\text{SO}_4$ ) and the pH before and after the water was processed by the HPT treatment system. All concentrations were expected to be at or below the goal levels specified in Table 1-1.

This report details the activities associated with meeting the project objectives. Appendix A of this report shows final results of sample analysis performed by ACZ Laboratories, Inc., of Steamboat Springs, Colorado. The analysis was performed on a an inductively coupled plasma (ICP) instrument in compliance with QAPP procedures. Appendix D and E results were previously analyzed at Lawrence Livermore National Laboratory on Berkeley Pit and Iron Mountain Mine AMD.

### **1.3 Quality Assurance Project Plan**

The approved QAPP is made part of this final report by reference. Technical and program materials contained in the QAPP will be repeated only to the extent required to ensure clarity in this report.

The performance-based requirements of the bench-scale demonstrations conducted were to test the ability of the HPT process to remove dissolved metals in Berkeley Pit water taken from the surface (oxidized) and the 200 foot level (unoxidized).

### **1.4 Demonstration Evaluation Standards**

Evaluation standards are stated in the Project QAPP and are detailed in Table 1-1.

Table 1-1. Data Quality Objectives of Accuracy, Precision, Method Detection Limit, and Completeness

Parameter	Units	Method Detection Limit	Precision (RPD)	Accuracy	Completeness	Critical Measurement	Goal Level (ppm)
Al	ppm	0.03	#20%	75-125%	95%	Yes	2.00
As	ppm	0.02	#20%	75-125%	95%	Yes	0.360
Cd	ppm	0.003	#20%	75-125%	95%	Yes	0.010
Cu	ppm	0.01	#20%	75-125%	95%	Yes	1.30
Pb	ppm	0.002	#20%	75-125%	95%	Yes	0.050
Ni	ppm	0.01	#20%	75-125%	95%	Yes	0.100
Zn	ppm	0.01	#20%	75-125%	95%	Yes	5.00
SO <sub>4</sub>	ppm	0.5	#20%	75-125%	95%	Yes	1500
pH	pH units	N/A	± 0.1	±0.1	95%	Yes	7-8 pH units

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## 2. HPT Technologies Process Description

### 2.1 Bench-Scale Process

Water from the Berkeley Pit was collected and transported to the laboratory at Montana Bureau of Mines and Geology at Montana Tech prior to testing. All metal precipitates were analyzed as part of a separate project and are not detailed in this report.

The bench-scale process for treating Berkeley Pit water was as detailed below.

1. Initial control samples of untreated water were collected and stored in acid-washed 250-milliliter (mL) high density polyethylene (HDPE) bottles according to the protocol described in standard operating procedure (SOP) #1 within the QAPP for analysis of dissolved metals nitrate ( $\text{NO}_3$ ) and  $\text{SO}_4$ . The initial pH of the untreated water was determined prior to treatment.
2. The water from the 200-foot level was treated by a series of three Ionic State Modification Chambers (ISM). A 500-mL sample was placed in ISM Reactor #1 where it was electrically treated for approximately 30 seconds. The solution was then transferred to ISM Chamber #2 where it treated for 10 to 15 seconds. The solution was transferred to the final ISM Chamber #3 and was treated for 10 to 15 seconds.
3. The treated water was transferred to a 1,000-mL beaker and placed in a magnetic ring, and two bases were added to the solution to raise the pH to a predetermined level. The mixture was slowly agitated for 3 to 5 minutes, and the pH was monitored to ensure that it stayed above the predetermined value. When the pH dropped below the predetermined value,

a small amount of base was added, and the slow agitation was continued.

Subsequently, the solution was allowed to stand for 5 to 10 minutes, and precipitates formed.

4. The solution was vacuum filtered through a 10-micron filter to separate the metal precipitates from the solution.
5. The filtered solution was placed in a clean 1,000-mL beaker where an appropriate amount of calcium hydroxide ( $\text{Ca}(\text{OH})_2$ ) was added to the solution to precipitate  $\text{SO}_4$  as gypsum. The solution was agitated for 2 to 3 minutes to allow the reaction to go to completion.
6. The resulting solution was vacuum filtered through a 10-micron filter to remove the gypsum precipitate.
7. The filtered solution was transferred to a clean 1,000-mL beaker, and sodium bicarbonate ( $\text{NaHCO}_3$ ) was added to lower the pH of the solution to between 7 and 8. A small amount of calcium carbonate ( $\text{CaCO}_3$ ) precipitated. The solution was filtered through a 5-micron filter.
8. Samples for analysis were taken in accordance with SOP #1 of the QAPP.
9. The same procedure was followed for the oxidized surface water samples.

### 2.2 Conclusion

The HPT AMD process produced water in compliance with the stated goals.

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### 3. Bench-Scale Demonstration

The demonstration was conducted from October 14, to 25, 1996, and activities took place in a general chemistry laboratory in the Engineering Laboratory Classroom Building of Montana Tech.

HTP Personnel present for the demonstration were:

- C J. Michael Overton, President
- C S.R. Wurzbarger, Vice-President
- C David Witter, Chief Financial Officer
- C David C. Triplett, Jr., Secretary
- C George Day, Chief Engineer

Support personnel from Montana Tech present at the demonstration were:

- C Steve Anderson, Project Manager,  
Berkeley Pit Innovative Technologies  
Project
- C Catherine Wassmann, Q/A Coordinator and  
Project Engineer
- C Jennifer Saran, Analytical Support

#### 3.1 Data Results

Values presented in Table 3-1 are in milligrams per liter or parts per million (mg/L or ppm). Indications of BDL represent Below Detectable Limits as defined by the ICP analytical

technique and specific instrumentation used by the conforming laboratory. It should be noted that the method detection limit (MDL) levels on 7-1 through 7-3 test runs are different than the MDLs on 7-4 and 8-1 test runs.

The MDL of each of the elements or ions measured is stated in the MDL column of the data results matrix presented in this paragraph. The MDL figures obtained were provided by the confirming laboratory (Appendix A).

Data in Table 3-1 was taken directly from the analytical results that were provided by the confirming laboratory. Originals of the analytical results data sheets furnished by the confirming laboratory are found in Appendix A.

Note: the MDL of ACZ Laboratory did not meet the testing capability levels described in the QAPP.

Samples were processed on October 21, 1996. Test runs 7-1 and 7-2 are from surface water, and test runs 7-3 and 7-4 are from the 200-foot-level water. Test run 8-1, processed on October 22, 1996, was also from the 200-foot level.

Table 3-1. Demonstration Results

	1993 Data	Test Sample Average BP1-BP3	7-1 Test Run	7-2 Test Run	7-3 Test Run	MDL	7-4 Test Run	8-1 Test Run	MDL	Statute Levels
Al	260 mg/L	294 mg/L	BDL	BDL	BDL	0.03 ppm	BDL	BDL	20 mg/L	2/0 mg/L
As	0.8 mg/L	2.6 mg/L	BDL	BDL	BDL	0.02 ppm	BDL	BDL	10 mg/L	0.36mg/L
Cd	2.14 mg/L	2.5 mg/L	BDL	BDL	BDL	0.003 ppm	BDL	BDL	2 mg/L	.010 mg/L
Cu	172 mg/L	185 mg/L	BDL	BDL	0.01 ppm	0.01 ppm	BDL	BDL	5 mg/L	1.3 mg/L
Pb	.031 mg/L	>1.0 mg/L	BDL	BDL	0.08 ppm	0.02 ppm	30 mg/L	10 mg/L	10 mg/L	0.05mg/L
Ni	.900 mg/L	1.0 mg/L	BDL	BDL	BDL	0.01 ppm	BDL	BDL	5 mg/L	0.1 mg/L
Zn	550 mg/L	605.5 mg/L	0.1 ppm	BDL	BDL	0.01 ppm	BDL	BDL	5 mg/L	5.0 mg/L
SO <sub>4</sub>	7,600 mg/L	10,800 mg/L	3,800	3,500	4,200	100 ppm	1,100 mg/L	900 mg/L	100 mg/L	500 mg/L
pH	2.85	2.90	12.2	12.1	12.2	0.1	11.9	Not Neutralized	Not Neutralized	6-9 pH units
*Note: The (MDL on tests 7-4 and 8-1 are very high because the samples had to be diluted 500 to 1 because of the residual calcium (the calcium was necessary to reduce the sulfate levels).										

### 3.2 Data Locations

Appendix A contains the actual test data on Berkeley Pit AMD used for this demonstration, and final data sheets on HPT 7-1 through 8-1 are from ACZ Laboratory.

Appendix B contains third-party test data from ACZ Laboratory where the calcium was not interfering with ICP metals.

Appendix C contains third-party test data done with an Optima ICP run by Dr. W.H. Chatham at Montana Tech's Analytical Laboratory.

Appendix D contains the first Lawrence Livermore National Laboratory noncustody samples of Berkeley Pit and Iron Mountain Mine AMD.

Appendix E contains the second Lawrence Livermore National Laboratory custody samples.

Appendix F contains the cover letter and report on third-party testing of AMD from the Iron Mountain Mine performed under the direction of Dr. Karl Longley at Cal State University, Fresno, California.

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## 4. Conclusions

### 4.1 General

Bench-scale demonstrations of innovative AMD remediation technologies conducted by HPT have shown:

- the ability of the HPT AMD process to remove metal ions from Berkeley Pit water to near or below equipment detection levels; and
- the ability of the HPT AMD processes to remediate Berkeley Pit AMD with environmentally safe chemical reagents.

### 4.2 Dissolved and Suspended Metals and Sulfates

Dissolved and suspended metals and sulfates that were part of this test were reduced by 99.98% using the HPT AMD process. Test runs 1-1 through 1-3 and samples HPT 2-1 through HPT 2-3 and samples HPT 3-1 through HPT 3-3 met this criteria. Due to the neutralization method chosen for this demonstration, several problems were caused at the confirming laboratory. Samples 7-4 and 8-1 were not neutralized.

### 4.3 pH

Target pH was 6 to 9 for treated waters from the HPT AMD process. In samples HPT 1-1 through HPT 1-3 and samples HPT 2-1 through HPT 2-3 and samples HPT 3-1 through HPT 3-3, this criteria was met. However, due to the neutralization method chosen for this test, it caused several problems at the confirming laboratory. Samples 7-4 and 8-1 were not neutralized.

### 4.4 SO<sub>4</sub>

While the sulfate concentration was not reduced to EPA standards, the testing was able to reduce the sulfate level to one-third of what standard chemistry is able to remove.

### 4.5 Consideration of Alternative Approach

The HPT AMD process is designed to produce water that complies with local, state, and federal regulations.

The sulfates in the AMD are converted to insoluble anhydrous calcium and magnesium sulfates. Testing of this material should be conducted to ascertain the best use of this by-product for possible agricultural use or as a building material.

Under the HPT AMD process, it is possible to remove the metals and a majority of the sulfates in one process.

### 4.6 New Diagram of Proposed Changes in HPT AMD Process

With the first test results from HTP's AMD process, two changes had to be made in the process to duplicate earlier test results.

In early September, HTP received the first shipment of the newly designed power supplies. The HPT 160 was built as a power source for the ISM pretreatment reactors. The Butte tests were the first time the HPT 160s were used on a full AMD test sequence. The computer controlled outputs were found to be very accurate, and because of that, results were out of the optimum voltage window for lead removal. One further change was made in the process. A fourth ISM pretreatment reactor (ISM #4-16A) was added for the oxidation of the lead ions. By adding the fourth ISM

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pretreatment reactor set for optimum lead voltage, the residual lead level was brought to 30 parts per billion (ppb) or below; this can be reached by simple lime addition. By using the fourth ISM reactor, Test 7-3 shows less than the instrument detection level (IDL) and 7-4 shows 30.4 ppb.

Testing done under the QAPP with the Optima ICP at Montana Tech (Appendix C) showed the HPT process removed all heavy metals (except lead) below 250 ppb. The residual lead, tests 5-1, 5-2 and 5-3, had lead levels from 437 to 589 ppb.

Problems were encountered in reducing the sulfate level to the low levels achieved in previous tests. The sulfate-precipitating chemical used, (analytical grade)  $\text{Ca}(\text{OH})_2$ , was not able to reproduce the results obtained with an agricultural lime.

This agricultural lime is being analyzed; however, preliminary tests show this lime contains significant amounts of magnesium oxide ( $\text{MgO}$ ); magnesium hydroxide ( $\text{Mg}(\text{OH})_2$ ); and magnesium carbonate ( $\text{MgCO}_3$ ) as well as some  $\text{CaCO}_3$ . At this time, the formula of this lime is being pursued so it can be reproduced.



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**Appendix A**  
**Actual Test Data on Berkeley Pit AMD Used For This Test**  
**And Final Data Sheets On HPT 7-1 Through 8-1**  
**From ACZ**

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**Appendix B**  
**Contains Third Party Test Data From ACZ Where The**  
**Calcium Was Not Interfering With ICP Metals**

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**Appendix C**  
**Contains Third Party Test Data Done With An Optima ICP**  
**Run By Dr. W.H. Chatham At Montana Tech Analytical Lab**

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**Appendix D**  
**First Lawrence Livermore National Laboratory Non-Custody**  
**Samples Of Berkeley Pit AMD, Butte Mt**

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**Appendix E**  
**Second Lawrence Livermore National Laboratory Tests**  
**Custody Samples**

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**Appendix F**  
**Cover Letter And Report On Third Party Testing of AMD**  
**From Iron Mt. Mine Performed By California State University Fresno**  
**Engineering Research Institute, Pinckall E. Longley and Dr. Barry H.**